Claims

1. An organic electronic device comprising at least two electrodes and a semiconducting layer comprising a mixture of at least one hole-transporting semiconducting material and at least one electron-transporting semiconducting material, wherein at least one of said semiconducting materials is in the form of semiconducting polymer brushes which are attached to the surface of at least one of said electrodes and are in contact with at least one of said other semiconducting materials.

2. An organic electronic device according to claim 1, wherein contact between said semiconducting polymer brushes attached to the electrode and said at least one other semiconducting material is achieved by either:
(a) intercalation of said at least one other semiconducting material with said semiconducting polymer brushes;
(b) growth of said at least one other semiconducting material as further semiconducting polymer brushes in the gaps between said first semiconducting polymer brushes to give an interpenetrating mixed polymer network; or
(c) by the polymerisation of a second, different monomer from the end of said semiconducting polymer brushes to give block co-polymer brushes having a bi-layer structure with direct covalent bonds between the said two or more semiconducting components.

3. An organic electronic device according to claim 1 or claim 2, wherein said device is selected from electroluminescent devices, photovoltaic devices, field effect transistors and liquid crystal devices.

4. An organic electronic device according to claim 3, wherein said device is a photovoltaic device.

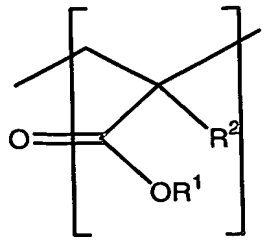
5. An organic electronic device according to claim 3, wherein said device is an electroluminescent device.

6. An organic electronic device according to any one of claims 1 to 5, wherein the average length of the polymer brushes is from 1 nm to 1 μm.

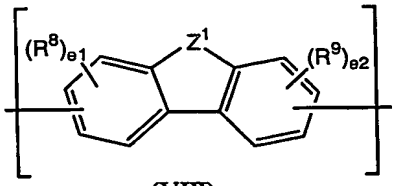
7. An organic electronic device according to any one of claims 1 to 5, wherein the average length of the polymer brushes is at least 40 nm.

8. An organic electronic device according to any one of claims 1 to 7, wherein said semiconducting polymer brushes are brushes wherein the polymer is selected from the group consisting of poly-phenylene-vinylene (PPV) and derivatives thereof, polyfluorene derivatives, polynaphthylene derivatives, polyindenofluorene derivatives, polyphenanthrenyl derivatives and poly(acrylate) derivatives.

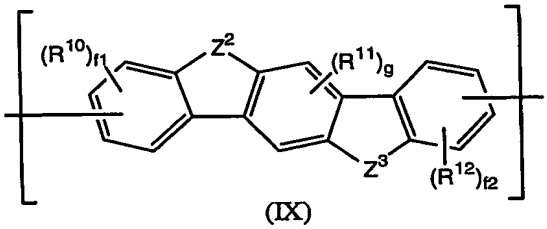
9. An organic electronic device according to any one of claims 1 to 7, wherein said semiconducting polymer brushes are brushes wherein the polymer is selected from the group consisting of polymers which include the following units of formulae (I), (VIII), (IX), (X), (XI), (XII), (XIII), (XIV) or (XV):



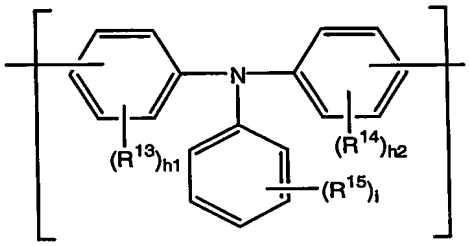
(I)



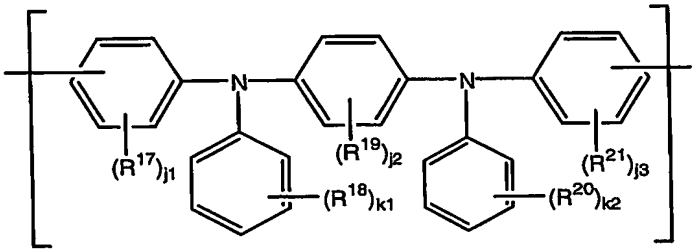
(VIII)



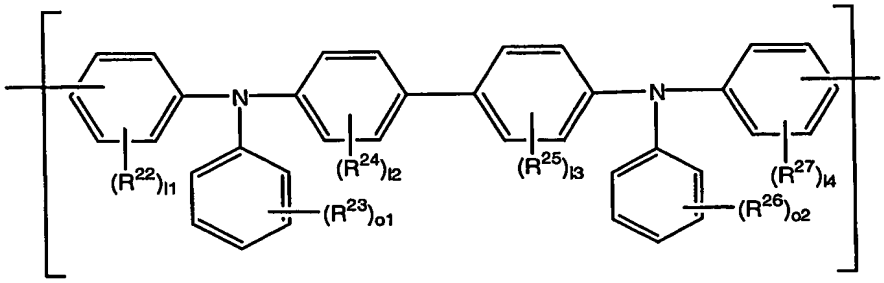
(IX)



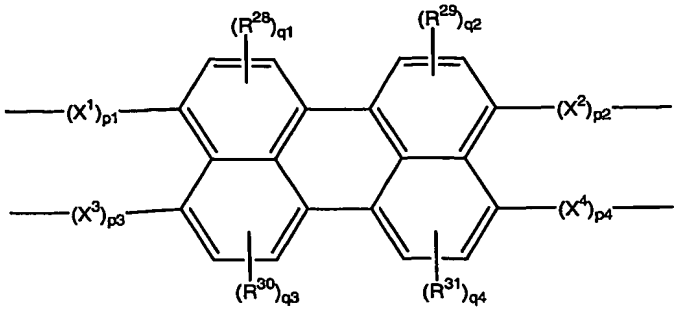
(X)



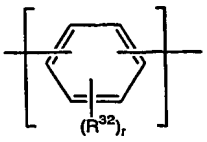
(XI)



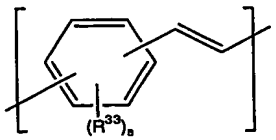
(XII)



(XIII)



(XIV)



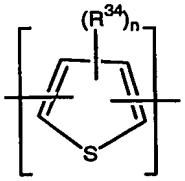
(XV)

wherein:

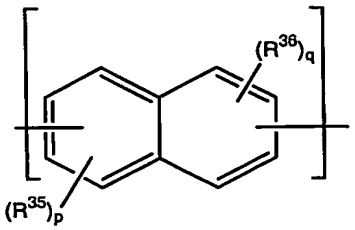
R^1 is a group of formula $-(CH_2)_m$-X-Y wherein

m is 0 or an integer of from 1 to 6,

X is a group of formula (X), (XI), (XII), (XIII), (XIV) or (XV) as defined above or a group of formula (II) or (III) as defined below



(II)



(III)

wherein

n is 0, 1 or 2,

p and q are the same or different and each is 0 or an integer of from 1 to 3, and

each of R^{34}, R^{35} and R^{36} is the same or different and is selected from the group consisting of alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below, aralkyl groups as defined below and groups of

formula $-COR^{16}$ wherein R^{16} is selected from the group consisting of hydroxy groups, alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below, aralkyl groups as defined below, amino groups, alkylamino groups the alkyl moiety of which is as defined below, dialkylamino groups wherein each alkyl moiety is the same or different and is as defined below, aralkyloxy groups the aralkyl moiety of which is as defined below and haloalkoxy groups comprising an alkoxy group as defined below which is substituted with at least one halogen atom,

or, where n, p or q is an integer of 2, the 2 groups R^{34}, R^{35} or R^{36} respectively may, together with the ring carbon atoms to which they are attached, form an aryl group as defined below or a heterocyclic group having from 5 to 7 ring atoms, one or more of said ring atoms being a heteroatom selected from the group consisting of nitrogen, oxygen and sulfur atoms, and

Y is selected from the group consisting of a hydrogen atom, R^{37}, NHR^{38} and $NR^{38}R^{39}$, wherein

R^{37} is selected from the group consisting of alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below, aralkyl groups as defined below and groups of formula $-COR^{16}$ wherein R^{16} is as defined above, and

each of R^{38} and R^{39} is the same or different and is selected from the group consisting of aryl groups as defined below and aralkyl groups as defined below;

R^2 is selected from the group consisting of group consisting of hydrogen atoms, alkyl groups as defined below, haloalkyl groups as defined below and alkoxy groups as defined below;

each of R^8 to R^{15} and R^{17} to R^{33} is the same or different and is selected from the group consisting of alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below, aralkyl groups as defined below and groups of formula $-COR^{16}$ wherein R^{16} is as defined above,

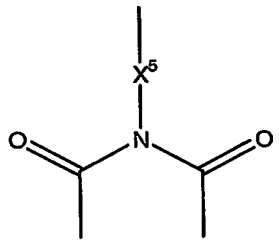
or, where r or s is an integer of 2, the 2 groups R^{32} or R^{33} respectively may, together with the ring carbon atoms to which they are attached, form a heterocyclic group having from 5 to 7 ring atoms, one or more of said ring atoms being a heteroatom selected from the group consisting of nitrogen, oxygen and sulfur atoms;

each of Z^1, Z^2 and Z^3 is the same or different and is selected from the group consisting of O, S, SO, SO_2, NR^3, $N^+(R^{3'})(R^{3''})$, $C(R^4)(R^5)$, $Si(R^{4'})(R^{5'})$ and $P(O)(OR^6)$, wherein R^3, $R^{3'}$ and $R^{3''}$ are the same or different and each is selected from the group consisting of hydrogen atoms, alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below, aralkyl groups as defined below, and alkyl groups as defined below which are substituted with at least one group of formula $-N^+(R^7)_3$ wherein each group R^7 is the same or different and is selected from the group consisting of hydrogen atoms, alkyl groups as defined below and aryl groups as defined below, R^4, R^5, $R^{4'}$ and $R^{5'}$ are the same or different and each is selected from the group consisting of hydrogen atoms, alkyl groups as defined below, haloalkyl groups as defined below, alkoxy groups as defined below, halogen atoms, nitro groups, cyano groups, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below and aralkyl groups as defined below or R^4 and R^5 together with the carbon atom to which they are attached represent a carbonyl group, and R^6 is selected from the group consisting of hydrogen atoms, alkyl groups as defined below, haloalkyl groups as defined below, alkoxyalkyl groups as defined below, aryl groups as defined below, aryloxy groups as defined below and aralkyl groups as defined below;

each of X^1, X^2, X^3 and X^4 is the same or different and is selected from:

arylene groups which are aromatic hydrocarbon groups having from 6 to 14 carbon atoms in one or more rings which may optionally be substituted by at least one substituent selected from the group consisting of nitro groups, cyano groups, amino groups, alkyl groups as defined below, haloalkyl groups as defined below, alkoxyalkyl groups as defined below, aryloxy groups as defined below and alkoxy groups as defined below;

straight or branched-chain alkylene groups having from 1 to 6 carbon atoms;
straight or branched-chain alkenylene groups having from 2 to 6 carbon atoms; and
straight or branched-chain alkynylene groups having from 1 to 6 carbon atoms; or
X^1 and X^2 together and/or X^3 and X^4 together can represent a linking group of formula (V) below:



(V)

wherein X^5 represents an arylene group which is an aromatic hydrocarbon group having from 6 to 14 carbon atoms in one or more rings which may optionally be substituted by at least one substituent selected from the group consisting of nitro groups, cyano groups, amino groups, alkyl groups as defined below, haloalkyl groups as defined below, alkoxyalkyl groups as defined below, aryloxy groups as defined below and alkoxy groups as defined below;
each of e1, e2, f1 and f2 is the same or different and is 0 or an integer of 1 to 3;
each of g, q1, q2, q3 and q4 is the same or different and is 0, 1 or 2;
each of h1, h2, j1, j2, j3, l1, l2, l3, l4, r and s is the same or different and is 0 or an integer of 1 to 4;
each of i, k1, k2, o1 and o2 is the same or different and is 0 or an integer of 1 to 5; and
each of p1, p2, p3 and p4 is 0 or 1;
the alkyl groups above are straight or branched-chain alkyl groups having from 1 to 20 carbon atoms;
the haloalkyl groups above are alkyl groups as defined above which are substituted with at least one halogen atom;
the alkoxy groups above are straight or branched-chain alkoxy groups having from 1 to 20 carbon atoms;

the alkoxyalkyl groups above are alkyl groups as defined above which are substituted with at least one alkoxy group as defined above; and
the aryl group above and the aryl moiety of the aralkyl groups (which have from 1 to 20 carbon atoms in the alkyl moiety) and the aryloxy groups above is an aromatic hydrocarbon group having from 6 to 14 carbon atoms in one or more rings which may optionally be substituted with at least one substituent selected from the group consisting of nitro groups, cyano groups, amino groups, alkyl groups as defined above, haloalkyl groups as defined above, alkoxyalkyl groups as defined above and alkoxy groups as defined above.

10. An organic electronic device according to claim 9, wherein said semiconducting brushes are homopolymeric brushes which comprise units of formulae (I), (VIII), (IX), (X), (XIV) or (XV).

11. An organic electronic device according to any one of claims 1 to 7, wherein said semiconducting polymer brushes are brushes wherein the polymer is selected from the group consisting of poly(4-diphenylaminobenzyl acrylate), PPV, poly(2-methoxy-5-(2'-ethyl)hexyloxy-phenylene-vinylene) (MEH-PPV), dialkoxy derivatives of PPV, dialkyl derivatives of PPV, and polyfluorene derivatives.

12. An organic electronic device according to any one of claims 1 to 7, wherein said semiconducting polymer brushes are brushes wherein the polymer is selected from the group consisting of poly(4-diphenylaminobenzyl acrylate), PPV, MEH-PPV, poly (2,7-(9,9-di-*n*-hexylfluorene)), poly (2,7-(9,9-di-*n*-octylfluorene)), poly (2,7-(9,9-di-*n*-octylfluorene)-(1,4-phenylene-((4-*sec*-butylphenyl)imino)-1,4-phenylene)) (TFB), and poly (2,7-(9,9-di-*n*-octylfluorene)-3,6-benzothiadiazole) (F8BT).

13. An organic electronic device according to any one of claims 1 to 12, wherein said at least one other semiconducting material is a semiconducting polymeric material or a semiconducting small organic molecule.

14. An organic electronic device according to claim 13, wherein said at least one other semiconducting material is either a semiconducting polymer selected from the group consisting of poly-phenylene-vinylene (PPV) and derivatives thereof, polyfluorene derivatives, polynaphthylene derivatives, polyindenofluorene derivatives, polyphenanthrenyl derivatives and poly(acrylate) derivatives, or a semiconducting small organic molecule selected from the group consisting of aluminium quinolinol complexes, perylene and derivatives thereof, complexes of transition metals, lanthanides and actinides with organic ligands such as TMHD and quinacridone, rubrene and styryl dyes.

15. An organic electronic device according to claim 14, wherein said semiconducting polymers are selected from polymers which include units of formulae (VIII), (IX), (X), (XI), (XII), (XIII), (XIV) or (XV) as defined in claim 9.

16. An organic electronic device according to claim 14, wherein said semiconducting polymers are selected from the group consisting of poly(4-diphenylaminobenzyl acrylate), PPV, poly(2-methoxy-5-(2'-ethyl)hexyloxy-phenylene-vinylene) (MEH-PPV), dialkoxy derivatives of PPV, dialkyl derivatives of PPV, and polyfluorene derivatives.

17. An organic electronic device according to claim 14, wherein said semiconducting polymers are selected from the group consisting of poly(4-diphenylaminobenzyl acrylate), PPV, MEH-PPV, poly (2,7-(9,9-di-*n*-hexylfluorene)), poly (2,7-(9,9-di-*n*-octylfluorene)), poly (2,7-(9,9-di-*n*-octylfluorene)-(1,4-phenylene-((4-*sec*-butylphenyl)imino)-1,4-phenylene)) (TFB), and poly (2,7-(9,9-di-*n*-octylfluorene)-3,6-benzothiadiazole) (F8BT).

18. An organic electronic device according to claim 14, wherein said semiconducting small organic molecules are selected from aluminium quinolinol complexes and perylene and derivatives thereof.

19. An organic electronic device according to any one of claims 1 to 12, wherein said at least one other semiconducting material is a semiconducting nanocrystalline material.

20. An organic electronic device according to claim 19, wherein said semiconducting nanocrystalline material is selected from semiconducting nanocrystals of cadmium selenide, lead selenide, zinc selenide, cadmium sulphide and zinc sulphide.

21. An organic electronic device according to claim 20, wherein said semiconducting material is cadmium selenide nanocrystals.

22. An organic electronic device according to any one of claims 1 to 21, wherein said electrode is coated with a hole-transport layer or an electron-transport layer before said polymer brushes are attached thereto.

23. An organic electronic device according to any one of claims 1 to 22, wherein said device is fabricated with polymer brushes of only a single species.

24. A process for the manufacture of an organic electronic device according to any one of claims 1 to 23, said process comprising:

(a) coating a substrate with a material to form one of the electrodes;

(b) optionally coating the electrode thus formed with a self-assembled monolayer end-capped with an initiator group or a self-assembled monolayer with the capability of forming a free radical;

(c) bringing the electrode, optionally coated with the self-assembled monolayer produced in step (b), into contact with a solution of a monomer under conditions suitable for the growth of polymer brushes comprising said monomer unit from the surface of said electrode;

(d) treating the product of step (c) in such a way as to produce a product in which the polymer brushes are in contact with at least one further semiconducting material; and

(e) coating a material on the top surface of the product of step (d) to form the further electrode.

25. A process according to claim 24, wherein said self-assembled monolayer comprises thiol molecules or siloxane molecules end-capped with an initiator group.

26. A process according to claim 24 or claim 25, wherein a hole transport layer or electron transport layer is deposited before optional step (b) or step (c).

27. An organic electronic device comprising at least two electrodes and a semiconducting layer comprising at least one hole-transporting semiconducting material or at least one electron-transporting semiconducting material, wherein said at least one semiconducting material is in the form of semiconducting polymer brushes which are attached to the surface of at least one of said electrodes.

28. An organic electronic device according to claim 27, wherein the device is a field effect transistor.

29. A process for the manufacture of an organic electronic device according to claim 27 or claim 28, said process comprising:

(a) coating a substrate with a material to form one of the electrodes;

(b) optionally coating the electrode thus formed with a layer of an electronically insulating material;

(c) optionally coating the electrode thus formed in (a), or following optional step (b), with a self-assembled monolayer end-capped with an initiator group or a self-assembled monolayer with the capability of forming a free radical;

(d) bringing the electrode, optionally coated with the self-assembled monolayer produced in step (c), into contact with a solution of a monomer under conditions suitable for the growth of polymer brushes comprising said monomer unit from the surface of said electrode;

(e) optionally coating the polymer brushes formed in (d) with a layer of an electronically insulating material;

(f) coating a material on the top surface of the product of step (d), or following optional step (e), to form the further electrode.

30. A process according to claim 29, wherein the electrode formed in (a) is coated with a layer of an electronically insulating material, as step (b).

31. A process according to claim 29, wherein the polymer brushes formed in (d) are coated with a layer of an electronically insulating material, as step (e).